TRANSLATION

PROBLEM NUMBER ONE -
RELIABILITY

By

A. I. Berg

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

WRIGHT-PATTERSON AIR FORCE BASE

OHIO

UNEDITED ROUGH DRAFT TRANSLATION

PROBLEM NUMBER ONE - RELIABILITY

BY: A. I. Berg

English Pages: 15

SOURCE: Russian Periodical, Tekhnika Molodezhi, Nr. 10, 1960, pp 7-10

S/29-60-0-10

Problem Number One - Reliability

by

A. I. Berg

The opinion prevails, that the more complex an object is (as if a fully valid rule) the less reliable it should be. Unfortunately, we have quite a number of such thinkers, supervisors of industrial enterprises, who, manufacture low quality roller bearings, electric and gas counters, automatic machines etc., insistently spread this opinion among the people.

The most curious thing of all, that these very same high headed supervisors are sincerely convinced, that it is just as they are thinking and no other way. They reason approximately so. The guarantee of faultless operation of one detail, let us say, equals 0.95 (95%). But if the unit has ten such details, then according to the theory of probability the reliability of the unit as a whole will be equal already to this coefficient, multiplied in itself ten times, i.e. $0.95^{10} = 0.6$. And if there a hundred details ! and if a thousand !

I suggest to all those, who developed a mathematical sense, to calculate, at what number of details in our example the reliability amounts to 1%. This will mean that in such a case only one person of a hundred has chances of buying, let us assume, a reliable electric counter. Ninetynine persons will curse "technology" and its "creators" because the purchased counters will practically not operate.

And all because of the complication of the details ! because of the desire of improving the detail !

Fortunately, the case is generally differnt. Otherwise we would have no, in particular, the remarkable successes in mastering outer space. But any one laborer of industr should constantly think about the mentioned danger. It is the present Damocles sword

over modern technical progress. If it would be so, as other industrial leaders are thinking, then people would have reason to dream (visualize)...about a stone axe. Its reliability would be a value close to 100%. A primitive person has not been concerned with the period of guarantee.

If we do not clearly understand the entire extend of danger, the technique of tomorrow may become obstructed. Progress may reach a "natural" boundary and stop there.

Quality should be Expressed by Quantity

Many directives call for an improvement in production quality. There are also instructions about planned introduction of new technique. But lacking are legitimate, general indices for numerical evaluation of quality.

The development of science goes from qualitative evaluations to accurate, mathematical, quantitative determinations. At present time it is absolutely insufficient to speak about the fact, that production quality is being increased, better etc. because this is just idle talk. In art and in literature, in music and estetics can be used terms "greater", "smaller", "higher", "lower" " more beautiful", "more complete ", "brighter", "lighter", "louder", " more interesting" etc. In science and technology this is absolutely prohibited. We would like to outdistance America not only generally, but to outdistance it with perfectly concrete quantitative characteristics. Among the number of these characteristics should figure also the production quality characteristic. Who can think of a greater number of these or any other objects, when each one of these objects is of low quality ?

That is why it is necessary to agree on establishing legitimate quantitative evaluations of the quality of ready made goods.

What indices can there be ? Unfortunately, nothing is clear in this problem. This problem has never been under consideration. This problem is also being weighed in foreign literature, however, evidently, there is no agreement there either.

What qualitative characteristics are being discussed ?

They differ in many branches of our industry: service life, accuracy, wear resistance, heat resistance, anticorrosion property etc. Reliability- probability of retaining the enumerated qualitative characteristics for a certain period of time. It is a generalized statistical, qualitative index, which gives a ready evaluation of many qualities of items.

The first objective indication of quality of goods can be the coefficient of reliability - number, smaller than one, expressing the probability of proper operation of the object for a given period of time under given conditions. We shall call it coefficient K_1.

We will assume that we have to execute a job in 100 kw/hr. This job should be completed within 20 hrs. It is evident, that if an absolutely reliable 5 kw capacity machine would be used, it will complete this job within 20 hrs. But let us assume, that the reliability coefficient of the available 5 kw machines is less than unity and equalling for example 0.5. Then one such machine, will probably, work correctly for only 10 gours of the 20 and will carry out within 20 hrs the useful operation in 50 kw-hr. Then one such machine will be capable of executing the required operation not within 20 but within 40 hrs, or it is necessary to use two such machines, which carry out the work in 100 kw-hr within 20 hrs.

Since the consumption of energy is connected with monetary expenditure, then the operation of nonreliable machines requires greater expenditures. It is clear from this simple example what the operation of unreliable machines can afford to do away with (and actually does away with).

But to evaluate the quality of an item with one reliability coefficient is impossible. We will assume, that the orderer knows for certain, that at present time the level of development of technology is such that the machine or object of definite type is capable of meeting certain definite requirements. The indices characterizing the object, can be entirely different depending upon what we are speaking about.

It can be the price, or power for given price, or weight, or service life, or the above discussed reliability coefficient

Illustration: Some high-minded constructors would prefer making machines in the spirit of a stone axe: heavy, but reliable.

These indices characterize objectively the level of development of the given branch of technology.

Illustration: Power of three machines is identical, why then does one of them give as much production as the two remaining ones? Because of a pair of machines, the reliability of which is 50%, one is always in repair.

It is possible and, unfortunately, highly probable, that the user, if he is not materially interested in the sale and manufacture of absolutely high quality products, corresponding to the present day level of development of technology, if he wants to work with a certain coefficient of reinsurance, finally if he is totally conscientious and honest, he will refuse to fulfill the requirements placed by the orderer and will agree to fill the order only with certain reduced qualities.

What is obtained then? By confering an agreement is reached, and the order is accepted not in conformity with the basic requirements of the orderer, but with reduced qualities. We will call the ratio of adopted characteristics to the possible coefficient of conformity. We designate it by K_2. It is apparent, that K_2 is also smaller

than one. This index may characterize, if convenient, also the probability, of fixing the order for the given item with indices, corresponding to modern technical possibilities.

It is further possible to repeat all deliberations, pertaining to the reliability coefficient. The result will be the same. Settle for a compromise when handling out the order will be the orderer, and the compromise will then be greater when the K_2 coefficient is lower.

The mentioned indices K_1 and K_2 characterize the operational reliability of the object, having lower than possible characteristics.

But this is still not all. It is known, that any object can work properly for a given period of time but only under conditions, that it will be periodically repaired.

We will not detail the problem so on what periodic repair is required. We are only interested in the fact, that in the time of its life, i.e. to total wear and thrown into scrap, the object should be idling for a definite period of time. It means that we should introduce still another coefficient K_3, which we will call the coefficient of utilization (at times it is also called the coefficient of readiness).

It is apparent, that K_3 does not coincide with the reliability coefficient K_1. For example, the electronic computer can function with a reliability coefficient $K_1 = 0.98$ and with the utilization coefficient $K_3 = 0.8$.

The object can either be in operation or in repair, or "relax". But as long as it works it does so with a reliability coefficient K_1. The selection of K_1 and K_3 indices depends upon many causes. There are cases that it is necessary to have an instrument working with very great reliability, but for a short period of time. It may be that high reliability is needed for a very long period of time. But at times there is no need that the reliability coefficient should be very high; the important thing is only, that the object should serve for a possibly long period of time of its entire service life.

The utilization coefficient characterizes also, as said before, to a certain

extent the probability of the item's readiness to work at each moment of time.

Now we are ready to introduce a certain objective quantitative index of product quality. It equals the product of the three above mentiçn characteristics,or coefficients. We will call i' quality coefficient or coefficient of item's effectiveness: $K = K_1 \cdot K_2 \cdot K_3$.

It is evident,that the closer the effectiveness coefficient of the item is to one ..e more will it satisfy its designation.

"Theory of Errors"

Speaking to the point, the tendency of assuring reliability in human blood.But this noble effort played a decisive role for our far off predecessors.

The fact is:why in the process of evolution in the development of the living world man has outlived and surmounted everything ? Because, he committed less errors,than his rivals. Those who erred perished in the merciless struggle for existence. They perished either because they themselves committed errors,or because of the errors of nature which took away from them the properties and signs,which were necessary for the purpose of surviving in a difficult situation,created by the outer medium and human society. Survived have the best adapted, who committed lesser errors, acting with greater purpose and more reliably.

By what is characteristic the entire activity of man, adapting himself to the conditions of the medium surrounding him and to the conditions,who has survived in the struggle for existence? He observed,he made guessing movements,collected information about attained results,guessing he took in his hands a stone,stick or other object and unexpectedly for himself he discovered and memorized, that these objects may be useful, i.e. he generalized his random acquired experience. And so man began thinking systematically.. His friends or enemies,who either did not make these random movements,or accidentally did not think analytically,perished, and he survived, and others survived,who pulled out the lucky lotery ticket. If these valu-

able properties have been transmitted to generations following, then they too survived in the process of natural choice.

Some people accidentally (since they still did not have a definite purpose) discovered the advisability (usefulness) of the structure of their hands and understood the desirability of reproducing their movements in simple mechanisms. The more curious ones discovered, that there are forces of nature, which can be helpful or disruptive. For example, water must be drunk to quench thirst, but it can also move a water wheel.

Illustrations: No imitations but natural things led our predecessor to the development of an oven, boat, clothing.

It is assumed that the Earth exists 3-4 billion years, that life in most primitive form was originated about 1.5 - 2 billion years ago, that human-like monkeys developed about a million years ago, and man in its present day form exists for about 50-70 thousand years, that approximately 40 thousand years ago he discovered that water and air can be utilized for the driving of his simple machines. But this does not mean, that he had then already his first water driven flour mill. This took many a thousand of years. It is known that 5 thousand years ago he was capable of doing it although in a very primitive way.

Man began using fire about 20-30 thousand years ago, but he used it in role of a source for heating water and to obtain steam (the existence of which he has not

previously surmised) only several hundred years ago.

The entire history of man's evolution - a continuous imitation of nature, continuous conversion (transformation) of the random into necessary. Securing the random which was found to be useful for preservation of the species, and transmission of same, in some way or another, to future generations. That is how the human brain was being developed, this genial creation of nature, material basis of reason, sense and memory.

To have a head and brain of larger volume man could not allow himself, because he would have perished from the nonconformity between the dimension of the head and the necessity of saving himself from danger together with his head with the aid of legs and arms. In this volume has gradually developed a system of ultraminiature, light and very reliably working nerve cells - neurons. They were found to be in the head in great numbers - about 10-15 billion.

But this brain served man good and bad. In it were born good and poor ideas. He created the tools of labor, mechanisms and machines to satisfy universal requirements, he also created the tools of war.

Regardless of the position-moral, social phylosophical- by which we can evaluate or criticize the arrangement and function of the brain, today it appears to us a totally unattainable ideal in many of its characteristics. One of the first ones-its ability to function reliably with greater reserves, with minimum loss of energy, utilizing for this fantastically small overall dimensions and weight. Our dreams about superminiature details and objects appears to be far away from it, which has been attained by nature during a stretch of millions of years, in the process of natural choice and struggle for existence.

Illustration: Creating electronic computers constructors have involuntarily obtained a general similarity of the brain. It is possible that it is necessary to search in the brain for examples for components of these machines ?

The brain has no concentrated mechanical masses and springs, individual capacitors, inductances and resistances, there is no vacuum. It consists of complex organic albumina substances, forming nerve tissues. It requires twenty times more oxygen, than the tissues of muscles (per unit of weight); the basic source of energy for the brain tissue appear to be carbohydrates, particularly glucose, which it utilizes two time more, than muscles. Ten billion neurons diffuse a power of about 10 w, i.e. 10^{-9} w per one neuron. In the cortex of the greater hemispheres of the brain - in humans it has a thickness of 2-5 mm-where the entire nervous activity of man is centered. (the entire higher nervous activity of man). The basic processes characterizing same - processes of excitation and inhibition. All these processes are connected with the existence of biocurrents in the brain, which can be detected, boosted and analyzed.

Although our data about the structure, composition and functions of the brain are at present time still far from complete and in many instances appear to be guesses, the fact of what we know forces us to be surprised by the expediency of its arrangement.

And yet such a brain functions slowly and this does not accomodate us. It has an insufficient memory volume and the unpleasant ability of forgetting what is necessary. It fatigues and stands no overloads, overwork and food deficiency. It does absolutely not endure vibrations and impacts, damages by dreadful pathological changes which can cause great losses to its owner and the surroundings.

That is why man decided to correct some of his deficiencies. Simple functions of the brain have been transplanted to electronic computers, the basic advantage of which - rapidity of action. But they are basically inferior to the brain since they work unreliably, requiring continuous and repeated checking of the operations, and this results in greater loss in time and considerable reduction in rate of operation.

Creating electronic machines, man is learning from nature, just as he learned from it to create equipment and tools of physical labor. But the brain is infinitely

more complex than arms and legs, and its modeling is at the very early stages.

Problems of "Mole Electronics"

Unwillingly the idea comes up: could we not borrow from the brain its structure? Since all processes taking place in the brain,-are electrical processes accompanying or combined with chemical and mechanical,is it not possible in technology to utilize elements of the system,having, like brain cells, a simultaneous capacitance,inductance and resistance and varying these parameters in conformity with need!

And is it possible to do away generally with individual elements? It is possible, that it is permissible to use monolithic blocks of materials,each one of which will execute a definite function of a unit of a radio electronic apparatus? It appears, that such a field of electronics has already acquired a certain initial development. It is called "Molecular Electronics", or "Molelectronics". It has the task of creating such a molecular structure of the substance, which would assure the properties,necessary for controlling a stream of charged particles for the purpose of attaining the necessary results.

Ultra pure crystals of semiconductors (1 atom of admixture per 10 billion atoms of matter) can be processed so that they will contain small amounts of necessary chemical admixtures and structural anomalies. The electric capacitances,inductances, resistances are replaced here by concepts of electronic spins, energy fields and electric interchanges. All these ideas,although well known to engineers,are unaccustomed to them.

Research in this direction is already underway. It is known that the Westinghouse Co. is germinating ligneous germanium crystals - thin homogeneous strips instead of round bars. Functional units of the apparatus have been created in form of monolithic germanium blocks - light telemetering amplifier with a volume of 0.015 cm^3 using only one element instead of fourteen in an ordinary transistor amplifier; created was a generator with a pulse repetition frequency of from 10 to 100 kc and pulse duration of up to 1 microsec. In this is also busily engaged another American comp,creating

so called "monolithic schemes" by deposition, pickling and diffusion; created were a diode, transistor, resistance and capacitance from one piece of silicon. By such methods have already been produced multivibrator and heterodyne with phase displacement.

The experimental multivibrator occupies a volume of 0.016 cm^3 and weighs 0.02 g. An improbably high density of arranging details - of the magnitude of 1200 pieces per 1 cm^3 has been attained. I will say for comparison, that in a conventional apparatus this density is thousands of times smaller. All these investigations are still in initial stage but they do deserve the most diligent attention because their purpose is to increase the reliability, reduce losses due to diffusion and to increase the number of functional units per unit of volume.

I cannot discuss other investigations and ideas in the field of microminiaturization, but it is well known, that they are carried on, on a broad front in many countries and may open a new era in radioelectronics.

There can be no doubt that these investigations and ideas are already beginning to penetrate into practice and they deserve most diligent attention. But I am convinced that they cannot be carried out by the homemade method, groups, consisting of several fanatics and enthusiasts. This is the not commenced margin of the work, a rich field for the application of forces and talents. Together with the existing groups should also be trained others, which must be solidly provided with most qualified cadres of chemists, metallurgists, crystallographers, physicists, radio experts and technologists. Particularly favorable conditions for their working must be provided and the most diligent attention must be paid to it.

A Friend is Appreciated in Need

We would like to discuss here still another highly important problem - reliability of man's work. More precise, the reliability of combined work of man and machine. This problem originates in connection with the fact that there is a baseless idea of replacing man with automat in the age of automation.

The fact is that only partial substitution does take place, but much more important is the fact, that under new conditions the man working on automated systems is confronted by new requirements.

If in times past, when physical labor was replaced by the work of machines, originated a problem of combined operation of man and machine, then now comes up the problem of combined operation of man and automat. This problem is not sufficiently bothering labor physiologists and psychologists. It is possible that under new conditions they forget about the limited psychic possibilities of man, working in a complex system, formed by machines, mechanisms, automats and living people. Man is capable with the aid of his organs of sense and brain to perceive, store and transform a limited amount of information per unit of time. If this boundary is exceeded, man can no longer orient himself in a situation too difficult for him.

Insufficient learning the psychic possibilities of man becomes particularly dangerous, when in the automated system occurs a certain misunderstanding. And such unpleasant things do sometimes how up, because in a complex system the combination of operating devices will sometimes suffer a break down, and this will cause a chain reaction of misunderstandings. In such a difficult situation man should orient himself rapidly, he should take part in the control and restore normal operation of the system.

Unfortunately automation is often figured only for "normal" operation and for proper action of all links and stops by itself when suffering damage, i.e. it happens namely then when it is expected to bring maximum use. During the stoppage of automatic installations are possible losses, by many times exceeding the advantages from its proper operation within a long period of time. Noone seems

Illustration: the time will come when repair of automats will become so difficult that man will not be able to work in it. The tasks will have to be carried out by themselves.

to think about and it is not taken into consideration when planning an automatic system.

That is why it is necessary to figure reliable operation of "man-automat" system not only when the achivements develop normally, but mainly for the case, when man has to say fast, what measures should be taken in case of operational failures of the automated process. This field of combined operation of labor psychology specialists and automation specialists. The investigations in this direction should be developed rapidly, otherwise we will not be able to prevent many misunderstandings which, will originate, no doubt, if they will appear to be unexpected.

All the things said here pertain to the field of reliability of man working under difficult conditions. Unfortunately this problem does not attract due attention, in any event, in many branches of industry and transportation. It is enough to mention, that at present time in our country are engaged 100 thousand switchman, tens of thousands of telephone operators at city and intercity stations. And how many are working on complex operations of qualified specialists: in cities and in villages are working hundreds of thousands of doctors, diagnosticians. But nobody systematizes the numerical quality indications of their work, particularly reliability qualities of their work under simple and difficult conditions. Technical progress frees man from heavy physical labor and places much stricter requirements to fatiguing labor, to reliability of action of man under new conditions.

In solving the problem of reliability there is a multitude of difficult theoretical strictly scientific problems. Their solution lies in the hands of outstanding mathematicians only. Included here are, e.g. problem of constructing a complex system, having much higher reliability, than its component elements, this is a problem of creating a reliable system of less reliable elements. On this problem are working for many years our mathematicians and engineers, as well as outstanding scientists of the West. This also takes in the problem of reliable control over a complex system of industrial relations. This includes the problem of creating analogues, models and rules, describ-

ing in a somewhat abbreviated form a complex system, which must be reliably controlled.

These problems should be solved by Institutions of the Academy of Sciences USSR, academies of sciences of allied republics, high educational institutions and leading industrial institutions.

In this way, I declare the necessity of changing over from general qualitative evaluation of new technique to accurate qualitative indices, which should be founded and legalized. These indices should figure in plans for the development of new technology. Among these a leading place should be taken up by the reliability index of items.

It is necessary to raise the responsibility for the manufacture of nonqualitative products, and particularly unreliable items.

It is necessary to assure combined operation of constructors, technologists and psychologists to assure normal performance of "man-automat " system not only during proper (correct) state of the system, but especially in case of functional failure.

One of the points of the resolution of the July session of the central committee of the communist party USSR reads: The session of the central committee of the communist party and the soviet of ministers of allied republics calls upon the parties, sovnarkhozes (ccops) and departments to raise the responsibility of plant supervisors, construction bureaus, scientific-research and planning organizations, upon all engineers-technical workers to raise the quality level of projects, construction of machines and equipment, technological processes, to improve the quality of manufactured products and expand its assortment, to raise industrial culture. It is necessary to carry on a decisive battle for the honor of industrial trade mark, against any kind of deviations from the technological conditions and violation of technical conditions".

These words inspire all people of labor and our famous youth in first place. The struggle to increase the quality and reliability of goods-a struggle for a better future of our entire country, for its technical progress. Young people should be in first lines also on this front.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE	Nr. Copies
HEADQUARTERS USAF	
AFCIN-3D2	1
ARL (ARB)	1
OTHER AGENCIES	
CIA	1
NSA	6
DIA	9
AID	2
OTS	2
AEC	2
PWS	1
NASA	1
ARMY	3
NAVY	3
RAND	1
NAFEC	1

MAJOR AIR COMMANDS	Nr. Copies
AFSC	
SCFDD	1
ASTIA	25
TDBTL	5
TDBDP	5
SSD (SSF)	2
APGC (PGF)	1
ESD (ESY)	1
RADC (RAY)	1
AFSWC (SWF)	1
AFMTC (MTW)	1
ASD (ASYIM)	1